Positioning Using Magnetic Anomalies Correlation of Earth (PUMACE)

Navy SBIR 21.3 - Topic N213-141

NAVWAR - Naval Information Warfare Systems Command

Opens: September 21, 2021 - Closes: October 21, 2021 (12:00pm edt)

N213-141 TITLE: Positioning Using Magnetic Anomalies Correlation of Earth (PUMACE)

OUSD (R&E) MODERNIZATION PRIORITY: Networked C3

TECHNOLOGY AREA(S): Sensors

OBJECTIVE: Develop Global Positioning System (GPS)-independent positioning sensors for accurate surface and subsurface vessel positioning that utilizes Earthï¿½s magnetic anomalies with an accuracy threshold of at least 30 meters and 15 meters (Objective) and has a Size, Weight and Power (SWaP) of 500 cm3 for the target volume, <5W for power and weight of <15 lbs.

DESCRIPTION: GPS is a highly accurate all-weather source of positioning, velocity, and timing and is invaluable in bounding a shipï¿½s inertial navigation systemï¿½s (INS) error. However, GPS utilizes weak radio frequency (RF) signals from distant satellites and are subjected to intentional and unintentional interference. Navigation based on the Earthï¿½s magnetic field promises a more robust all-weather passive navigation with no dependence on new infrastructure.

Magnetic anomaly navigation has been extensively explored and researched, most notably by the Air Force Institute of Technology; however, challenges remain in the availability of precise maps of the Earthï¿½s crustal magnetic field. The presence of larger core fields, as well as temporal variations, can further limit the precision of position accuracy. Additionally, locally induced magnetic fields of the ship itself must also be considered in the determination of position. Furthermore, there are limitations to current Geomagnetic Mapping that requires advanced modeling techniques. For example, the International Geomagnetic Reference Field (IGRF) model only accounts for the core field. Crustal field variation sensing could result in accurate positioning; however, because the crustal field is so weak in comparison to core fields, it also requires advanced vector sensors. Current-generation sensors are limited because they are scalar sensors and, therefore, not capable of sensing minute variations of the Earthï¿½s crustal field.

Advanced magnetic anomaly sensors can provide reliable and accurate INS aiding. These sensors can also work effectively to bound inertial error by providing re-sets to the INS. Additionally, they can provide a precise, all-weather robust vertical reference to bound INS errors over time. This family of sensors can promise robust positioning using integrated systems that are capable of blending alternate positioning sensor data as a re-set of the INS for continued accurate platform navigation holdover without GPS dependency. In addition to INS aiding, the data can be used as another sensor source for integrity evaluation within the Position, Navigation, and Timing (PNT) suite.

PHASE I: Determine the technical feasibility of using measurements of anomalies in the Earthï¿½s magnetic field for accurate Geomagnetic Mapping, as well as the identification of sensors necessary to detect magnetic field anomalies for accurate positioning.

Describe the technical solution based on the investigation and technical trade-offs performed earlier in this phase. Identify the means to incorporate the technical solution into the PNT suite, such as the GPS-based Positioning Navigation and Timing Service (GPNTS).

For the identified solution, develop the SBIR Phase II Project Plan to include a detailed schedule (in Gantt format), spend plan, performance objectives, and transition plan for the identified Program of Records (PoRs).

PHASE II: Develop a set of performance specifications for the Positioning Using Magnetic Anomalies Correlation of Earth (PUMACE) sensor with positioning solution system for GPNTS and conduct a System Requirements Review (SRR).

Engage with the Program Office in its introduction and collaboration with Naval Information Warfare Center (NIWC) Pacific engineers. Establish a working relationship with PMW/A 170 and NIWC Pacific engineers to perform integration studies to include the identification of any necessary engineering changes to the GPNTS system. Additionally, establish a working relationship with the engineering team(s) of other potential transition PNT suite target(s).

Develop the prototype PUMACE sensor with positioning solution system for GPNTS for demonstration and validation in the GPNTS or equivalent development environment. Conduct a Preliminary Design Review (PDR) and commence development of an Engineering Development Model (EDM) system. Conduct a Critical Design Review (CDR) prior to building the EDM.

Develop the life-cycle support strategies and concepts for the system.

Develop a SBIR Phase III Project Plan to include a detailed schedule (in Gantt format) and spend plan, performance requirements, and revised transition plan for the GPNTS and other potential transition PNT suite target(s).

PHASE III DUAL USE APPLICATIONS: Refine and fully develop the Phase II EDM to produce a Production Representative Article (PRA) of the PUMACE sensor.

Perform Formal Qualification Tests (FQT) (e.g., field testing, operational assessments) of the PRA PUMACE sensor with the GPNTS system and other potential transition PNT suite target(s).

Provide life-cycle support strategies and concepts for the PUMACE sensor with the GPNTS and other potential transition PNT suite contractor(s) by developing a Life-Cycle Sustainment Plan (LCSP).

Investigate the dual use of the developed technologies for commercial applications, including but not limited to, commercial and privately owned vessels and aircrafts. These sensors can provide an additional method of positioning that is independent of GPS and is available at all times, world-wide.

REFERENCES:

1. "Magnetic-Field Navigation as an 'Alternative' GPS?" Evaluation Engineering, 27 October 2020. https://www.evaluationengineering.com/applications/article/21160035/magneticfield-navigation-as-an-alternative-gps

2. "Magnetic Anomaly." Wikipedia, the Free Encyclopedia. https://en.wikipedia.org/wiki/Magnetic_anomaly

3. Mount, Lauren A. "Navigation using Vector and Tensor Measurements of the Earth's Magnetic Anomaly Field." (2018). AFIT Scholar Theses and Dissertations. 1817. https://scholar.afit.edu/etd/1817

4. Canciani, Aaron J. "Absolute Positioning using the Earthï¿½s Magnetic Anomaly Field." (2016). AFIT Scholar Theses and Dissertations. 251. https://scholar.afit.edu/etd/251

KEYWORDS: Earthï¿½s Magnetic Fields; Magnetic Sensors; Magnetic Anomalies; GPS-based Positioning, Navigation, and Timing Service; GPNTS; Position, Navigation, and Timing; PNT; Assured Position, Navigation, and Timing; APNT; Positioning; Navigation; Global Positioning System; GPS; Positioning Using Magnetic Anomalies Correlation of Earth; PUMACE

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